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Balancing Forage and Legumes: Impact on Goat Feed Intake and Nutrient Digestibility

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Goats play a vital role in livestock production systems, particularly in smallholder farming, providing valuable meat, milk, and fiber sources. However, maximizing goat productivity is contingent upon providing a balanced and nutritious diet. This study evaluated the impact of elephant grass-legume mixtures on nutrient consumption and digestibility in goats, aiming to identify the most effective combination for enhancing feed efficiency. Using a 4x4 Latin Square Design, four goats (14–25 kg) were fed four treatments: P1 (70% elephant grass + 30% Moringa), P2 (70% elephant grass + 30% Indigofera), P3 (70% elephant grass + 30% Lamtoro), and P4 (70% elephant grass + 30% Gamal). Key findings showed that the Lamtoro mixture (P3) achieved the highest nutrient consumption and digestibility, outperforming other treatments. Unlike previous studies, this research underscores the comparative advantages of specific legume combinations, with Lamtoro demonstrating significant potential as a superior forage option for small ruminants. These results highlight the critical role of balanced forage-legume mixtures in enhancing goat productivity and advancing sustainable livestock systems.

Keywords: Elephant grass utilization, forage management, goat feeding strategy, sustainable agriculture, ruminant performance, nutritional digestibility, protein rich fodder.

INTRODUCTION

Goats play an essential role in smallholder farming systems, providing valuable sources of meat, milk, and fiber. Increasing the productivity of female goats is closely tied to feed availability, both in terms of quality and quantity. Feed is a critical component that must be supplied adequately to support goats' growth, development, and reproduction. Forages, provided in either fresh or dry form, serve as the primary feed source for ruminants. Commonly used forages include grasses such as elephant grass and Bengal grass, as well as legumes like Indigofera, Gamal, Lamtoro, Moringa, and Turi. These legumes are particularly valued for their high nutritional content, especially their crude protein levels.

Forages are classified into grasses (Graminae) and legumes (Leguminoseae). The primary difference between these two groups lies in their nutritional profiles, particularly their crude fiber and protein contents. Elephant grass (*Pennisetum purpureum*) is a widely cultivated forage valued for its high yield, palatability, and adaptability to various environments, making it an excellent feed for goats (Infitria and Khalil, 2014). Its ability to thrive in diverse climatic conditions and produce consistent biomass ensures reliable feed availability throughout the year, particularly in smallholder farming systems (Kusuma *et al*., 2015). Additionally, its moderate protein content and digestible fiber make it a suitable base for balanced diets when combined with nutrient-rich legumes (Kusuma *et al*., 2015).

Legumes, on the other hand, are highly regarded for their superior nutritional attributes. They are rich in essential amino acids, which complement the often protein-limited composition of grass-based diets. Certain legumes, such as Lamtoro, also offer higher energy content, supporting metabolic activities and growth. Additionally, legumes are excellent sources of vitamins, particularly vitamin A and B-complex vitamins, as well as minerals like calcium and phosphorus, which are essential for bone development and physiological processes. Moreover, legumes can enhance

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rumen function by stimulating microbial activity, thereby improving fiber digestibility and overall feed efficiency.

Among legumes, Gamal leaves contain crude protein (16.82–25.08%), crude fiber (8.61–24.57%), crude fat (2.19–12.29%), ash (6.67–10.15%), and total digestible nutrients (TDN) of 35.42–40.21% (Nurlaha *et al.*, 2015). Moringa leaves provide high nutritional value, with crude protein content reaching 29.16% and nitrogen-free extract (NFE) at 28.55% (Osfar, 2008). Lamtoro leaves also offer notable nutrient composition, including crude protein at 21.5% and NFE at 49.5% (Yurmiaty and Kusmajadi, 2007). Indigofera leaves are rich in crude protein (23.66–31.1%) and minerals such as calcium (3.08–3.21%) and phosphorus (0.22–0.35%) (Abdullah, 2010). These attributes position legumes as an ideal complementary feed to grasses in meeting livestock nutritional needs.

Energy and protein are fundamental for livestock to meet their maintenance, growth, and production requirements. Protein, in particular, plays a crucial role in promoting body weight gain, metabolic functions, and tissue repair. The amount of feed consumed and its digestibility significantly influence nutrient absorption and utilization. Total digestibility is affected by feed nutrient composition, livestock species, environmental conditions, feed palatability, and processing techniques (Nahak *et al.*, 2024).

Integrating legumes with grasses has been shown to enhance feed intake, nutrient digestibility, and overall performance in ruminants, as demonstrated in previous studies (Cherdthong *et al.*, 2021). For instance, Lamtoro and Moringa have been identified as valuable legumes due to their high protein and balanced fiber profiles. However, certain legumes, such as Indigofera and Moringa, contain antinutritional factors like tannins, which can reduce protein digestibility and palatability. These limitations can be mitigated through processing techniques such as ensiling or drying, improving their utilization (Cherdthong *et al.*, 2021).

Digestibility studies in ruminants are typically conducted using in vivo, in sacco, or in vitro techniques (Zubaili *et al.*, 2017). The in vivo method, used in this study, analyzes feed and feces using live animals, providing accurate insights into nutrient digestibility in the digestive tract. Although slightly less precise than in vitro methods, it offers a realistic evaluation of feed utilization (Somanjaya and Dani, 2017).

Given the importance of optimizing feed consumption and nutrient digestibility, this study aimed to evaluate the effects of different legume-grass mixtures on feed intake and digestibility in goats. By highlighting the unique nutritional advantages of specific legumes and the adaptability of elephant grass, this study contributes to the development of sustainable feeding strategies for small ruminants.

MATERIALS AND METHODS

***Ethical approval and study location*:** All animal use procedures adhered to the guidelines for the care and use of animals in research and were approved by the Animal Ethics Committee of the Faculty of Medicine, Hasanuddin University, Indonesia (Approval Number: 783/UN4.64.5.31/PP36/2024). The study was conducted at the goat barn of the Ruminant Nutrition Feed Test Unit, Faculty of Animal Husbandry, Hasanuddin University.

***Experimental design and feeding*:** The experiment utilized a 4x4 Latin Square Design involving 4 animals and 4 treatments to ensure balanced comparisons and minimize variation among treatments. Four *kacang* goats, with an average body weight of 14–25 kg, were used for the study. The animals were rotated across four periods to receive different treatments based on the design.

The experimental diets used in this study are a combination of elephant grass and legumes (Moringa, Indigofera, Lamtoro, and Gamal). Each treatment consisted of a mix of 70% elephant grass and 30% one of the four legumes. The feed compositions for the four treatments were as follows:

- P1: 70% Elephant Grass + 30% Moringa
- P2: 70% Elephant Grass + 30% Indigofera
- P3: 70% Elephant Grass + 30% Lamtoro
- P4: 70% Elephant Grass + 30% Gamal

Each treatment was randomly assigned for one goat in each period, as presented in Table 1.

Table 1. Allotment of treatment according to 4x4 Latin Square Design.

Period	Goat 1	Goat 2	Goat 3	Goat 4
I	P1	P2	P3	P4
II	P3	P4	P2	P1
III	P2	P1	P4	P3
IV	P4	P3	P1	P2

Each goat was placed in a stage cage equipped with containers for feed and drinking water. For feces collection, a green gauze net was installed beneath each cage to facilitate feces collection. The study was conducted over four periods, comprising a five-day adaptation phase followed by a five-day observation phase. Feed and water were provided ad libitum, and the leftover feed was weighed each morning to calculate daily feed consumption.

***Digestibility measurement*:** Digestibility measurements were conducted using the total collection method over the five-day observation phase. Feces were collected continuously for 24 hours each day. The fresh feces from each goat were weighed daily to record fresh weight. The feces were then dried under sunlight until fully dehydrated, after which they were re-weighed to determine the dry matter content. For analysis, fecal samples collected over the five-day period were homogenized. A subsample of 400–500 grams was taken

Table 2. Chemical composition of forage and legumes.

Chemical components (%)	Elephant Grass	Moringa Leaves	Indigofera Leaves	Lamtoro Leaves	Gamal Leaves
Dry Matter	16.43	19.87	23.52	24.99	24.00
Organic Matter	88.99	88.03	90.57	85.05	90.17
Crude Protein	9.45	26.73	22.12	24.44	25.43
Crude Fiber	36.39	17.73	18.30	17.27	19.90
Ether Extract	1.98	6.95	4.18	6.88	5.38
NFE	41.17	36.32	45.97	36.46	39.46
NDF	75.69	29.55	33.78	21.79	35.61
ADF	42.40	24.38	24.76	19.44	22.73
Cellulosa	33.29	16.29	17.72	16.81	14.91
Hemicellulose	35.29	5.17	9.02	2.35	12.88
Lignin	5.28	7.42	6.85	2.30	7.42

Source: Feed Chemistry Laboratory of the Faculty of Animal Husbandry, Hasanuddin University, 2023.

from the homogenized feces, oven-dried, and ground into a fine powder for laboratory analysis.

***Laboratory analysis*:** Proximate analysis (AOAC, 2019) and Van Soest analysis (Goering and Van Soest, 1976) were performed on feed and feces samples to determine the following components:

- Proximate Analysis: Moisture content, crude protein (CP), crude fiber (CF), crude fat (EE), ash, and nitrogen-free extract (NFE).
- Van Soest Analysis: Neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose, and hemicellulose.

The chemical components of the experimental diet (forage and legumes) are presented in Table 2.

***Parameters observed*:** The parameters observed in this study are feed consumption and digestibility of the experimental diet. Nutrient consumption was calculated using the following formula:

Consumption of DM (g) = Amount of feed offered (g) x %DM of Feed – Feed residue (g) x %DM of feed residue

For OM, CP, CF, EE, NFE, consumption was calculated as follows:

Nutrient consumption (g) = (DM Consumption × Nutrient Content of Feed) − (Feed Residue × Nutrient Content of Feed Residue)

Fiber consumption, i.e. NDF, ADF, Cellulose, and Hemicellulose was calculated as follows:

Fiber consumption = (DM Consumption × Fiber Content of Feed) − (Feed Residue × Fiber Content of Residue)

***Digestibility*:** Digestibility is the percentage of a nutrient consumed that is not excreted in the feces. The difference between nutrient intake and fecal nutrient output is divided by the nutrient intake to determine digestibility:

Digestibility of nutrients, i.e. DM, OM, CP, CF, EE, NFE, NDF, ADF, Cellulose, and Hemicellulose, was calculated using the following general formula:

Digestibility (%) = Nutrient Consumed (Nutrient Consumed − Nutrient in Feces) × 100

***Data analysis*:** Data were analyzed by analysis of variance according to a 4 x 4 Latin Square Design (4 treatments and 4 replications). The treatments that significantly affected the parameters measured were then tested using the Duncan test with the following mathematical model (Sudjana, 1991).

$$Y_{ijk} = \mu + \beta_i + K_j + T_k + \xi_{ijk}$$

Description:

μ = general mean

ßi = effect of row to (1, 2, 3, 4)

Kj = column effect to (1, 2, 3, 4)

Tk = treatment effect to (1, 2, 3, 4)

ξ ijk = error effect.

RESULTS

***Feed consumption*:** Based on data from research obtained in the field, the feed consumption of goats fed with a mixture of elephant grass and legumes is presented in Table 3.

The analysis of nutrient consumption (Table 3) revealed significant differences among treatments ($P<0.05$) for most parameters. Dry Matter (DM) consumption was highest in P3 (447.94 g/head/d), significantly greater than P1 (255.13 g/head/d) and P2 (254.74 g/head/d), while P4 (370.21 g/head/d) was intermediate. This suggests that the inclusion of Lamtoro leaves in P3 improved palatability and feed intake. The higher DM content in Lamtoro (24.99%) compared to Moringa (19.87%) and Indigofera (23.52%) likely contributed to this effect, as higher DM content supports greater feed intake. P4, containing Gamal (24.00% DM), also showed higher DM consumption, reflecting its intermediate acceptability.

A similar trend was observed for Organic Matter (OM) consumption, with P3 (398.74 g/head/d) significantly outperforming P1 (226.37 g/head/d) and P2 (225.89 g/head/d), while P4 (328.00 g/head/d) was intermediate. The

Table 3. Average nutrient consumption according to the treatment.

Nutrient consumption (g/head/d)	Treatment			
	P1	**P2**	**P3**	**P4**
Dry Matter	255.13±21.21[a]	254.74±19.04[a]	447.94±44.70[b]	370.21±98.44[ab]
Organic Matter	226.37±21.67[a]	225.89±16.90[a]	398.74±38.46[b]	328.00±87.32[ab]
Crude Protein	44.97±4.19[a]	44.98±4.10[a]	76.10±6.97[b]	64.72±18.27[ab]
Crude Fiber	84.35±10.02	78.32±12.80	131.28±25.79	100.38±20.56
EE	9.03±0.86[a]	7.99±0.63[a]	19.69±1.12[b]	13.99±3.92[ab]
NFE	98.81±8.42[a]	109.72±7.48[ab]	174.01±18.20[b]	148.19±38.93[ab]
NDF	85.47±3.32[a]	81.10±5.10[a]	146.66±13.04[b]	118.73±33.55[ab]
ADF	139.70±4.34[a]	130.45±14.12[a]	238.65±26.33[b]	190.10±51.08[ab]
Cellulose	47.19±5.99	50.61±4.97	90.07±14.20	87.19±22.52
Hemicellulose	16.33±5.74[a]	53.96±4.46[ab]	85.34±14.48[b]	95.17±11.84[b]

[ab]Means sharing different superscripts at similar rows differed ($P<0.05$). P1= Elephant grass 70% + Moringa leaves 30%, P2 = Elephant grass 70% + Indigofera leaves 30%, P3 = Elephant grass 70% + Lamtoro leaves 30%, and P4 = Elephant grass 70% + Gamal leaves 30%.

high OM in Indigofera (90.57%) and Gamal (90.17%) contributed to moderate consumption in P2 and P4, but Lamtoro's balanced OM content (85.05%) facilitated greater intake in P3.

Crude Protein (CP) consumption was significantly higher in P3 (76.10 g/head/d) compared to P1 (44.97 g/head/d) and P2 (44.98 g/head/d), with P4 (64.72 g/head/d) being intermediate. This reflects the high protein content in Lamtoro leaves (24.44%) and Gamal leaves (25.43%) compared to Indigofera (22.12%) and Moringa (26.73%). The relatively lower protein consumption in P1 and P2 suggests that factors other than crude protein content, such as fiber or secondary metabolites, may have limited intake.

For Ether Extract (EE) consumption, P3 (19.69 g/head/d) significantly outperformed P1 (9.03 g/head/d) and P2 (7.99 g/head/d), with P4 (13.99 g/head/d) showing intermediate results. This is consistent with the higher fat content in Lamtoro (6.88%) and Gamal (5.38%), supporting their greater intake. Nitrogen-Free Extract (NFE) consumption followed the same pattern, with P3 (174.01 g/head/d) being significantly higher than P1 (98.81 g/head/d), while P2 (109.72 g/head/d) and P4 (148.19 g/head/d) were intermediate. The high NFE consumption in P3 reflects the digestible carbohydrate availability in Lamtoro, which encourages feed intake.

For fiber components, Neutral Detergent Fiber (NDF) consumption was highest in P3 (146.66 g/head/d), significantly greater than P1 (85.47 g/head/d) and P2 (81.10 g/head/d), with P4 (118.73 g/head/d) being intermediate. Similarly, Acid Detergent Fiber (ADF) consumption was significantly higher in P3 (238.65 g/head/d) compared to P1 (139.70 g/head/d) and P2 (130.45 g/head/d), with P4 (190.10 g/head/d) being intermediate. This reflects Lamtoro's lower NDF (21.79%) and ADF (19.44%) content compared to Indigofera (33.78% NDF and 24.76% ADF), making it more digestible and encouraging higher intake.

For cellulose consumption, P3 (90.07 g/head/d) and P4 (87.19 g/head/d) had significantly higher consumption values compared to P1 (47.19 g/head/d) and P2 (50.61 g/head/d), reflecting the higher cellulose content in Lamtoro (16.81%) than in Moringa (16.29%) and Gamal (14.91%). The higher cellulose consumption in P3 and P4 numerically indicated a higher palatability level of lamtoro leaves and gamal leaves.

For Hemicellulose, P3 (85.34 g/head/d) and P4 (95.17 g/head/d) had significantly higher consumption compared to P1 (16.33 g/head/d), reflecting the moderate hemicellulose content in Lamtoro (2.35%) and Gamal (12.88%) compared to Moringa (5.17%). The higher hemicellulose consumption in P3 and P4 indicates improved fiber digestibility and palatability.

***Nutrient digestibility*: **Based on data from research obtained in the field and the results of fecal analysis in the laboratory, the digestibility of feed for goats fed with a mixture of elephant grass and legumes is presented in Table 4.

Nutrient digestibility analysis (Table 4) revealed significant differences among treatments for most parameters. For Dry Matter (DM), P3 (82.49%) had the highest digestibility, significantly greater than P2 (68.74%), with P1 (70.66%) and P4 (77.29%) being intermediate. This reflects the superior nutritional balance and lower fiber content in Lamtoro, which facilitated better rumen fermentation. P2's lower DM digestibility is likely due to higher fiber fractions in Indigofera (NDF 33.78%, ADF 24.76%), which are less digestible.

Organic Matter (OM) digestibility followed a similar trend, with P3 (78.38%) outperforming the other treatments, though differences were not statistically significant. Crude Protein (CP) digestibility was highest in P3 (89.80%), significantly greater than P2 (78.81%), with P1 (80.42%) and P4 (83.20%) being intermediate. The high protein content in Lamtoro (24.44%) and its balanced fiber and fat content supported better microbial protein synthesis, enhancing digestibility.

Table 4. Average nutrient digestibility according to the treatment.

Nutrient consumption (g/head/d)	Treatment			
	P1	**P2**	**P3**	**P4**
Dry Matter	70.66±4.00[ab]	68.74±1.67[a]	82.49±2.87[b]	77.29±6.59[ab]
Organic Matter	62.23±4.71	62.91±2.24	78.38±2.00	72.22±9.08
Crude Protein	80.42±2.41[ab]	78.81±4.66[a]	89.80±3.65[ab]	83.20±8.94[ab]
Crude Fiber	58.16±9.22	60.83±7.75	75.47±5.96	68.00±6.96
EE	47.17±6.95	38.14±7.65	74.63±2.89	61.41±13.86
NFE	62.10±5.77	34.16±2.17	76.72±2.53	71.47±7.76
NDF	54.21±1.18[a]	53.36±3.62[a]	74.27±2.18[b]	64.80±10.51[ab]
ADF	50.96±1.94[ab]	48.73±2.72[a]	69.69±2.63[b]	59.74±13.71[ab]
Cellulose	29.64±2.77[a]	41.32±5.12[ab]	75.54±3.37[b]	64.62±9.67[ab]
Hemicellulose	62.62±7.72	49.06±7.81	59.00±7.31	79.00±3.12

[ab]Means sharing different superscripts at similar rows differed ($P<0.05$). P1= Elephant grass 70% + Moringa leaves 30%, P2 = Elephant grass 70% + Indigofera leaves 30%, P3 = Elephant grass 70% + Lamtoro leaves 30%, and P4 = Elephant grass 70% + Gamal leaves 30%.

For Crude Fiber (CF) digestibility, P3 (75.47%) was the highest, reflecting Lamtoro's lower fiber content and higher degradability. In contrast, P2 (60.83%) and P1 (58.16%) had lower values, with P4 (68.00%) being intermediate. Ether Extract (EE) digestibility was significantly higher in P3 (74.63%) compared to P2 (38.14%), with P1 (47.17%) and P4 (61.41%) being intermediate. The higher fat content in Lamtoro (6.88%) enhanced energy availability and digestibility in P3.

Nitrogen-Free Extract (NFE) digestibility was highest in P3 (76.72%), significantly greater than P2 (34.16%), with P1 (62.10%) and P4 (71.47%) being intermediate. The quality of carbohydrates in Lamtoro likely contributed to its superior NFE digestibility, while Indigofera's lower digestibility may reflect a higher proportion of less digestible polysaccharides.

For fiber components, Neutral Detergent Fiber (NDF) digestibility was highest in P3 (74.27%), significantly greater than P2 (53.36%), with P1 (54.21%) and P4 (64.80%) being intermediate. Similarly, Acid Detergent Fiber (ADF) digestibility was significantly higher in P3 (69.69%) compared to P2 (48.73%), with P1 (50.96%) and P4 (59.74%) showing intermediate values. Cellulose digestibility was highest in P3 (75.54%), significantly outperforming P1 (29.64%), with P2 (41.32%) and P4 (64.62%) being intermediate. Hemicellulose digestibility was highest in P4 (79%), followed by P3 (59%), while P1 (62.62%) and P2 (49.06%) showed lower values.

DISCUSSION

***Nutrient consumption*:** The dry matter (DM) consumption observed in this study, ranging from 254.74 to 447.94 g/head/d, aligns with the standards reported by Kusuma *et al.* (2015), which indicate that tropical goats typically consume 1.8 to 4.7% of their live weight in DM daily. The chemical composition of the feed, particularly its protein, fiber, and fat content, plays a critical role in influencing feed intake. Palatability, as emphasized by (Kusuma *et al*., 2015), is a key determinant of DM consumption and is shaped by the physical and chemical properties of the feed, including its odor, texture, and taste.

Organic matter (OM) consumption, ranging from 225.89 to 398.74 g/head/d, exhibited a pattern consistent with DM consumption since OM constitutes a significant component of DM. The higher OM consumption in P3 (Lamtoro leaves) compared to P2 (Indigofera leaves) reflects differences in protein content and carbohydrate composition. Rehatta *et al*. (2023) suggested that feeds with higher protein levels and easily degradable carbohydrates enhance OM consumption. The positive correlation between DM and OM intake observed in this study aligns with findings by Djita *et al*. (2019), who noted that reduced DM consumption typically results in lower OM consumption due to their compositional relationship.

Crude protein (CP) consumption was significantly higher in P3 (76.10 g/head/d) than other treatments, likely due to the higher CP content in Lamtoro leaves. Protein is an essential nutrient that supports rumen microbial activity and energy production, as noted by Kharismawan *et al*. (2020). Additionally, the chemical composition of feed affects its palatability, which influences CP intake. For example, the decrease in CP consumption in P4 (64.72 g/head/d) compared to P3 may be attributed to the higher fiber content in Gamal leaves, which reduces palatability (Kadir and Intan, 2019).

Crude fiber (CF) consumption was lowest in P2 (78.32 g/head/d), possibly due to Indigofera leaves' relatively high CF content. High fiber levels slow digestion, reduce energy availability, and induce satiety, leading to lower feed consumption, as described by Prawitasari *et al*. (2012). De Carvalho *et al*. (2010) similarly highlighted that excessive fiber levels increase rumen fill, reducing feed intake. Conversely, P3, which contained more balanced fiber levels, exhibited the highest cellulose consumption, reflecting a more favorable chemical composition for intake. As Aling *et al*.

(2020) noted, the chemical structure of cellulose, as a major component of CF, directly influences feed intake based on its ease of breakdown by rumen microbes.

Ether extract (EE) consumption ranged from 7.99 to 19.69 g/head/d, with the highest value observed in P3. This is directly linked to the higher fat content in Lamtoro leaves, as EE consumption correlates with the dietary fat composition (Nugraheni *et al*., 2022). Tillman *et al*. (1998) emphasized that fats are more energy-dense than other macronutrients, and their presence in the feed stimulates intake by providing readily available energy. However, the variation in EE consumption across treatments may also be influenced by differences in feed formulation, which affects both chemical composition and palatability.

Nitrogen-free extract (NFE) consumption was significantly higher in P3 (174.01 g/head/d) compared to P1 (98.81 g/head/d), primarily due to its higher carbohydrate availability. NFE represents the soluble carbohydrate fraction, which provides energy that directly impacts feed consumption (Luruk *et al*., 2024). The elevated NFE consumption in P3 highlights the role of carbohydrate composition in stimulating feed intake. Feeds with more soluble and degradable carbohydrate fractions tend to promote higher intake by providing easily accessible energy, as noted by Aling *et al*. (2020).

NDF consumption, which represents the total cell wall components (hemicellulose, cellulose, and lignin), was significantly higher in P3 (146.66 g/head/d) compared to P1 (85.47 g/head/d) and P2 (81.10 g/head/d), with P4 (118.73 g/head/d) being intermediate. The elevated NDF intake in P3 reflects the favorable balance of digestible fiber and palatability in Lamtoro leaves. High NDF consumption suggests better utilization of structural carbohydrates for rumen microbial fermentation, as noted by Cindy *et al*. (2020). Conversely, the lower NDF intake in P2 may be attributed to the relatively higher lignin content in Indigofera leaves, which reduces fiber digestibility and overall feed preference. This trend aligns with Saputro (2015), who observed that high lignin content in feed components limits intake by increasing rumen fill and inducing satiety.

ADF consumption, indicative of less digestible fiber components like cellulose and lignin, was also significantly higher in P3 (238.65 g/head/d) compared to P1 (139.70 g/head/d) and P2 (130.45 g/head/d), with P4 (190.10 g/head/d) being intermediate. The superior ADF intake in P3 suggests that Lamtoro leaves strike a balance between palatability and digestibility despite their higher ADF content. High ADF levels generally reduce feed intake due to slower fermentation rates, as highlighted by De Carvalho *et al*. (2010), yet the fiber quality in P3 appears to mitigate this effect. In contrast, the lower ADF intake in P2 reflects Indigofera's higher lignin concentration, which impedes microbial breakdown and reduces feed consumption.

Cellulose consumption ranged from 47.19 g/head/d in P1 to 90.07 g/head/d in P3, with P3 showing the highest intake. This aligns with the better digestibility of cellulose in Lamtoro leaves, which enhances its contribution to energy supply through rumen fermentation (Aling *et al*., 2020). The relatively lower cellulose intake in P1 and P2 can be attributed to less digestible fiber fractions, as Wahyono *et al*. (2019) noted that high lignin content in forages limits microbial access to cellulose. P4 exhibited a comparable cellulose intake to P3 (87.19 g/head/d), suggesting that Gamal leaves also provide a favorable cellulose source, albeit less consistent than Lamtoro.

Hemicellulose consumption was significantly higher in P4 (95.17 g/head/d) and P3 (85.34 g/head/d) compared to P1 (16.33 g/head/d) and P2 (53.96 g/head/d). The superior hemicellulose intake in P4 and P3 reflects the lower lignin association and higher hemicellulose digestibility in Gamal and Lamtoro leaves, promoting higher feed consumption (Wawo *et al*., 2020). As a more easily fermentable fiber fraction, hemicellulose directly influences rumen fermentation efficiency, supporting better nutrient utilization. The low hemicellulose intake in P1 may be due to antinutritional factors in Moringa leaves, such as tannins, which reduce palatability and fiber utilization (Windoro *et al*., 2020).

***Nutrient digestibility*:** The significantly higher dry matter digestibility (DMD) observed in P3 (elephant grass + Lamtoro leaves) compared to other treatments is primarily attributed to its higher crude protein (CP) content and lower levels of indigestible fiber components such as lignin. As McDonald *et al*. (2002) explained, feed digestibility is influenced by its chemical composition, with fibrous feeds exhibiting slower degradation due to the inhibitory effects of lignin on microbial activity. Syaputra *et al.* (2013) further noted that reduced lignin levels allow for more efficient microbial digestion, which is evident in the higher DMD of P3. Conversely, the lower DMD in P2 (elephant grass + Indigofera leaves) reflects the higher fiber content in Indigofera, which impedes enzymatic and microbial access to digestible components.

Organic matter digestibility (OMD) mirrored the trends observed for DMD, with P3 showing the highest value. OM digestibility reflects the overall availability of essential nutrients such as carbohydrates, proteins, and lipids (Suardin *et al*., 2014). The superior OMD in P3 aligns with its higher nutrient availability and balanced fiber composition, as Mangangang *et al*. (2020) noted, who linked higher DMD to greater OM availability. In contrast, the lower OMD in P2 may be due to the reduced digestibility of its fiber fractions, which limits nutrient absorption.

Crude protein digestibility (CPD) was highest in P3 (89.80%), supported by the higher CP content in Lamtoro leaves (24.44%) and their balanced fiber composition. As noted by Kadir and Intan (2019), protein digestibility is strongly

influenced by the CP content of the ration, with lower CP levels leading to reduced digestibility. The lower CPD in P2 (78.81%) reflects Indigofera's relatively lower protein content (22.12%) and higher fiber levels, which limit the availability of protein for rumen microbial synthesis. This trend aligns with Diwi *et al*. (2020), who observed that higher CP digestibility correlates positively with livestock productivity and weight gain.

The highest crude fiber digestibility (CFD) was recorded in P3 (75.47%), which is consistent with its higher crude fiber intake and lower lignin content. Sutrisno *et al*. (2022) noted that optimal fiber digestibility in goats typically ranges between 30% and 80%, emphasizing the importance of a balanced fiber composition. The lower CFiD in P2 (60.83%) reflects the higher lignin and cellulose content in Indigofera leaves, which impede fiber breakdown by rumen microbes. Excessively high fiber levels can also hinder the digestion of other nutrients, reducing overall feed efficiency (Ilhamsah *et al*., 2020).

Ether extract digestibility (EED) was significantly higher in P3 (74.63%) compared to other treatments, likely due to the higher fat content in Lamtoro leaves (6.88%). As Rahmawati *et al*. (2021) explained, fats typically exhibit higher digestibility than proteins or carbohydrates due to their simpler chemical structure. In contrast, the lower EED in P2 (38.14%) may be related to the higher fiber content in Indigofera leaves, which interferes with fat digestion by limiting microbial activity.

NFE digestibility was highest in P3 (76.72%), reflecting the high quality and availability of soluble carbohydrates in Lamtoro leaves. Luruk *et al*. (2024) noted that NFE, composed of readily fermentable sugars and starches, contributes directly to microbial energy production, enhancing feed utilization. The lower NFE digestibility in P2 (34.16%) is likely due to more complex polysaccharides, which are less accessible to rumen microbes.

NDF digestibility was also highest in P3 (74.27%), supported by its balanced fiber profile and lower lignin content (2.30%). Wahyono *et al*. (2019) emphasized that high lignin content in forages, as observed in Indigofera (6.85%), restricts microbial access to hemicellulose and cellulose, reducing NDF digestibility. The intermediate NDF digestibility in P4 (64.80%) suggests that Gamal leaves provide a good balance of fiber components, albeit less optimal than Lamtoro.

The highest ADF digestibility was recorded in P3 (69.69%), reflecting the lower lignin and cellulose content in Lamtoro leaves. Siswanto *et al*. (2016) explained that high lignin levels, as seen in P2, inhibit cellulose and hemicellulose microbial degradation, reducing ADF digestibility. This is consistent with Wibowo *et al*. (2019), who noted that lignin binds to cellulose, forming complexes resistant to microbial breakdown.

Cellulose digestibility was highest in P3 (75.54%), highlighting the role of lower lignin levels in enhancing microbial access to cellulose (Wijayanti *et al*., 2012). In contrast, the reduced cellulose digestibility in P2 (41.32%) reflects the inhibitory effects of Indigofera's high lignin content. The intermediate digestibility observed in P4 (64.62%) indicates that Gamal leaves provide a good source of digestible cellulose, though slightly less efficient than Lamtoro.

Hemicellulose digestibility was highest in P4 (79%) and P3 (59%), with the superior performance of Gamal leaves likely due to their high hemicellulose content and relatively low lignin levels. Hambakodu *et al*. (2018) noted that lignin significantly affects hemicellulose digestibility by forming lignohemicellulose complexes, which are difficult for rumen microbes to degrade. The lower hemicellulose digestibility in P1 (62.62%) and P2 (49.06%) reflects the higher lignin content and presence of antinutritional factors in Moringa and Indigofera leaves, respectively.

***Study Limitations*:** While this study provides valuable insights into the impact of elephant grass-legume mixtures on nutrient consumption and digestibility in goats, several limitations should be acknowledged. First, the limited number of animals used in the study may affect the generalizability of the results to larger goat populations. Second, the short duration of the experimental period may not fully capture long-term effects of dietary interventions on goat productivity and health. Additionally, environmental factors, such as housing conditions and climatic variations, were not explicitly controlled, which could influence feed intake and nutrient digestibility. Future studies with larger sample sizes, extended feeding trials, and controlled environmental conditions are recommended to validate and expand upon these findings.

***Conclusion*:** The combination of elephant grass with lamtoro leaves (P3) exhibited the highest nutrient consumption and digestibility, attributed to its superior protein content, moderate fiber levels, and digestible carbohydrates, making it the most effective forage for goats. P2 (Indigofera leaves) showed the lowest performance due to higher lignin and less digestible fiber fractions, while P1 (Moringa) and P4 (Gamal) produced intermediate results, with P4 slightly outperforming P1. These findings emphasize the importance of selecting legumes with optimal chemical composition to enhance livestock productivity.

***Recommendation*:** Lamtoro leaves (P3) are recommended as the primary forage for goats due to their superior nutrient consumption and digestibility, while Gamal leaves (P4) serve as a suitable alternative. Indigofera (P2) should be limited due to its high lignin content. Future research should explore feed formulations and processing techniques, such as ensiling and tannin-binding agents, to enhance the palatability and digestibility of less effective forages, supporting sustainable livestock production.

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***SDGs addressed*:** Zero Hunger; No Poverty; Responsible Consumption and Production

***Policy referred*:** FAO's Sustainable Livestock Development Policy, National Livestock Development Policies.

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